Microcontroller based low power led driver with a soft switched sepic converter

Dr.Kavitha P[1], Kalaiarasan. A[2], Kishore Kumar B[3], Ganeshmoorthy G[4]
[1] pkt.eee@rmkec.ac.in. [2] kalale191216.ee@rmkec.ac.in [3]kish18236.ee@rmkec.ac.in
[4] ganeshg_be@yahoo.com
[1] Department of EEE, R.M.K. Engineering College, Kavaraipettai, Tiruvallur 601206, Tamil nadu India
[2,3] UG students Department of EEE, R.M.K. Engineering College, Kavaraipettai, Tiruvallur 601206, Tamil nadu India
[4]Samsung Pvt Ltd, Chennai Tamil nadu India

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Abstract

Background: This paper intend an economical design of a low power light emitting diode (LED) driver with a soft switched SEPIC converter and a parallel connected high frequency series L-C resonant inverter. The conferred structure extort a rectifier powered SEPIC derived power factor controller (PFC) which minimize the harmonic distortion of the line current by rising the input power factor. On the load side, a high frequency transformer is embraced for isolation and rectifier to offer proper voltage and current to the load. The design contains a feedback loop to control the switching operation of the SEPIC converter by varying its duty cycle. The soft switching application produces to reduce the noise due to electromagnetic interference (EMI). This inverter is controlled using two sinusoidal pulse width modulation (PWM) signals of 20 kHz. This paper adopts the low cost 8 bit microcontroller to provide the driver advantage of effortlessly coupled system in home automation and remote controlled lamps. The model was simulated using a simulation tool. The total harmonic distortion (THD) of the supply line current is around 10% at 0.98 power factor at the sending end.

Keywords: SEPIC converter, EMI noise, LED driver, sinusoidal PWM, series L-C resonant inverter, soft-switching, THD.

1. Introduction

Owing to widespread lifetime, small dimension, extreme robustness, less weight, less emission of radiation and high color output, LEDs are superior alternate for customary luminous lights particularly in case of street, motorized vehicles and living accommodations illumination applications. LEDs were modeled as constant voltage loads with restricted current source feature for suitable illumination characteristics. Hence driver is essential to deliver appropriate power quantities such as voltage and current to the LED load. Since the load is connected with the AC supply, isolation is important in designing LED drivers for electrical protection measures. Owing to the noteworthy advances in production technologies which enables major developments in (LEDs) for lighting applications [1-5] that also reduces the energy consumption.

The intensity of the LED depends on the current flowing through it hence an proficient control is required to control the LED current. The driver circuit is connected to commercial AC input voltage of 230 V rms and provides it to the LED lamp which functions with DC current. The driver circuit also regulates the LED current and does power factor correction. The driver must be compact, good life span and with the lowest permissible cost.[6]-[9]

The types of AC-DC converters are single and two stage topologies. The two stage converters have more advantages such as quick output response, high efficiency, provide unity power factor but the size is increased. Single stage topologies are the mostly preferred since it posses single dynamic switch, maximum efficiency, almost unity power factor, single control loop and reduced size when compared to double stage topologies. Boost converter topology is often used because of its simple structure and reduced filter size. Due to its characteristics of stepping up of voltage the bus voltage is increased which is a drawback in LED drivers. A one stage isolated AC-DC driver with voltage doubled converter for LED has a distinct inductor half bridge design with magnetic control is discussed in [3]. The multi sequence LED driver gives high performance than a single string LED [3]. An input inductor less buck–boost converter would be affected by unendurable electromagnetic interference (EMI) effects; hence it requires a large passive filter at the output.[10]-[15]

Soft switching techniques such as Zero voltage switching (ZVS) and Zero Current switching (ZCS) may be used in the LED driver circuits designed for reducing the losses due to high frequency switching which can be designed by using resonant converters in place of DC-DC converters. A number of novel topologies for soft-switching enabled LED drivers were proposed. [16] - [18].

The normally involved topologies for low power and minimal expense AC-DC change for private lighting applications is Flyback converter. At the point when it works in irregular conduction mode, the input harmonics are less however the voltage stress on the parts is extremely high. A proper snubber circuit ought to be modelled and incorporated to stifle the ringing caused because of leakage inductance of the transformer which makes the plan more intricate [19]-[20].

This paper proposes a microcontroller based low power LED driver with a soft switched SEPIC converter a parallel-loaded high recurrence series L-C resounding inverter. In this topology the internal EMI is decreased due to soft switching which shows a decrease of switching Impulses during on-off state change periods. By bringing down the impedance of the circuit, the resonant arrangement result power loss of the inverter. This paper is coordinated as follows: Segment II presents the equivalent circuit of LED, block diagram Segment III presents the proposed converter topology with its functioning. Segment IV deals with analysis and design of the converter and the components used in its implementation. Section V presents reproduction and exploratory simulation and experimental outcomes got by utilizing model. Segment VI reports final conclusion.

2. Equivalent circuit of LED and Functional Block diagram

2.1 Equivalent circuit of LED and its V-I characteristics

Based on the data sheet, the working current of pronounced brightness white LED is 200 to 700 mA and its distinctive drive voltage is 2.3 to 4 V. The equivalent circuit and V-I graph of the LED is as presented in Fig. 1.

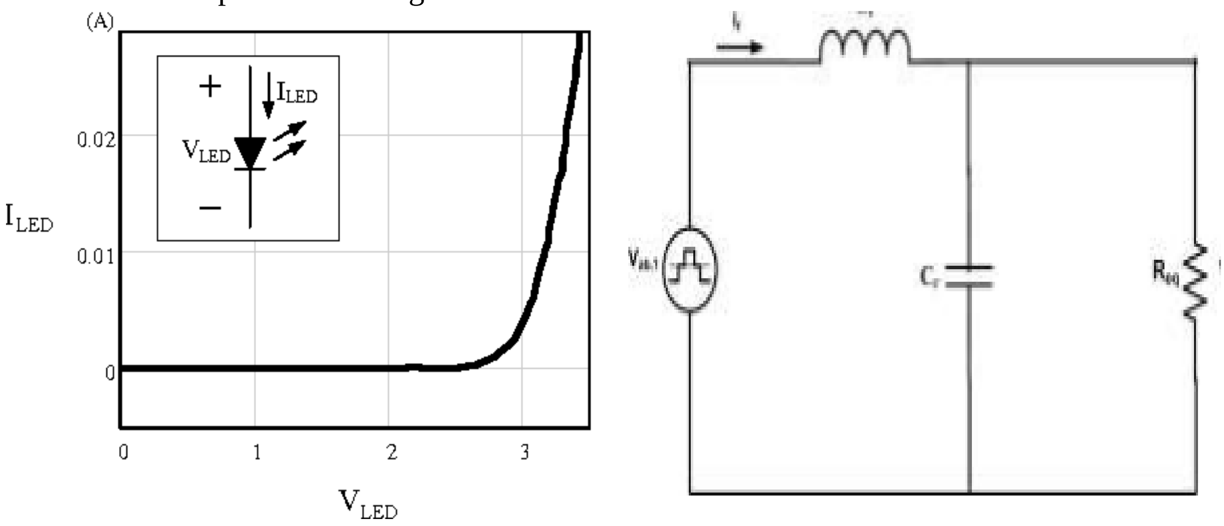

Fig1. Equivalent circuit and V-I graph of LED

The light emitted by single LED is comparatively less; hence LEDs are connected in series as well as parallel to escalate the illumination. The brightness of LED is dependent mainly on the current through it hence an efficient control is required to regulate the current. The driver takes the AC input voltage of 230 V and delivers it to the LED lamp which operates with DC current. The driver regulates the LED current and also unity power factor correction. The cost, size, and life time are the major concerns of the driver.

2.2. Block diagram

Fig. 2 shows the block diagram of the microcontroller-based LED lamp driver. It contains various blocks namely the AC mains, harmonic filter at the input side, Rectifier unit SEPIC converter connected to LED load through DC link inverter. The driver circuit receives necessary commands from the microcontroller which can provide high frequency pulses to meet the current demand of the LED to meet the brightness demand. The necessary power supply required for the micro controller and driver circuit is also shown.

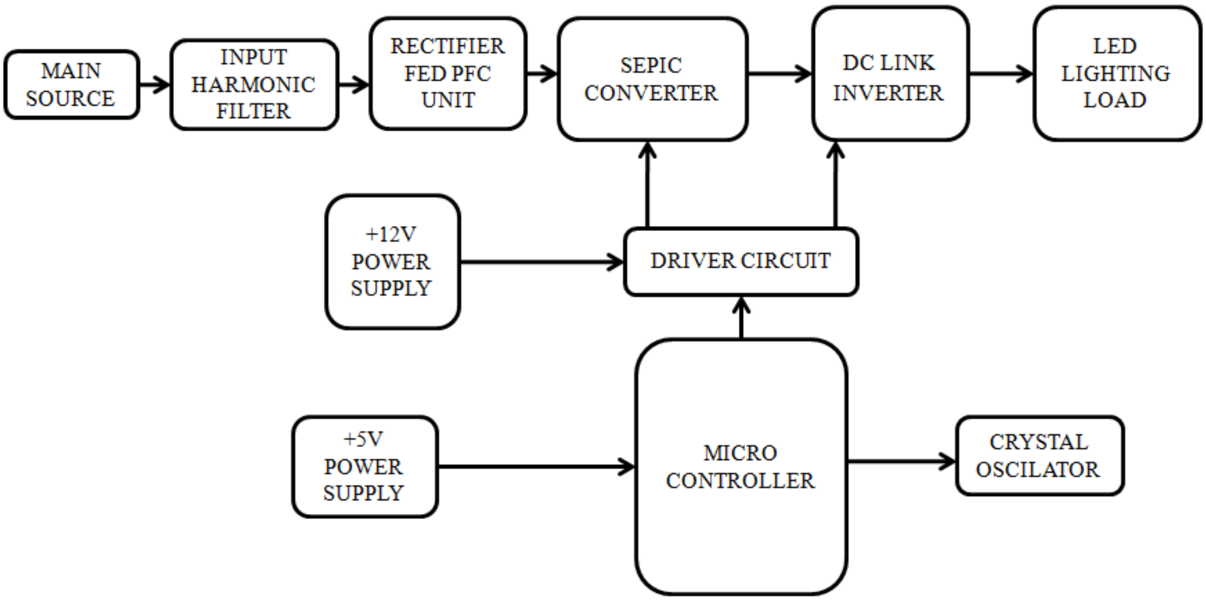

Fig2. Block diagram

2.3 Converter topology

The LED lamp driver using conventional PFC based SEPIC converter is shown in Fig. 3. Which operates in the discontinuous conduction mode (DCM) to accomplish the benefits of one stage power conversion, high power factor, minimized component count and simple controller. On the other hand it also has the drawback of high voltage stress on its components. The low power LED driver integrates a rectifier-fed-buck derived PFC unit, a second stage soft switching controlled SEPIC converter to generate an appropriate dc voltage level followed by a parallel connected series L-C resonant inverter circuit to yield an equivalent high frequency output which is suckled into a receiving-end rectifier through a high frequency transformer. The LED lighting is a steady voltage load undifferentiated from the physical and functional characteristics of a diode. Fig. 3 shows the driver topology thinking about a sensible plan for functional acknowledgment. The PWM beats are produced by a programmable strategy utilizing a microcontroller, to control the exchanging activity of the proposed converter. The switch recurrence for the planned PFC and the full inverter is kept consistent at 20 kHz. The soft-switching function capability of the converter limits the turning motivations during fast turn on and switch off changes by interfacing a tiny worth of inductance with an equivalent series resistance (ESR) at the input port. These series L-R decrease current spikes at the change time of exchanging and thus lessen the inward EMI commotion which is additionally alluded as di/dt parts.

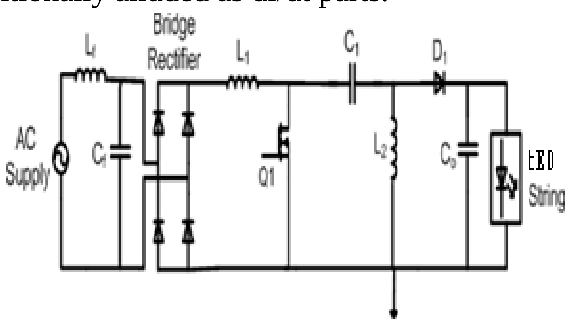

Fig3. Conventional SEPIC PFC converter

Entire dc dc converters function by quickly turning on and off a MOSFET, with a high frequency switching pulse. For SEPIC converter, if the rate of pulse is high then the MOSFET is turned on, inductor L1 is charged by the supply voltage and inductor L2 is charged by capacitor C1. The diode is reverse biased and the output is maintained by capacitor C2. If the pulse is low the MOSFET is turned off, then inductor tend to discharge through the diode then to the load and the capacitors are charged. If the amount of duty cycle of the pulse is less, the output will be more. Because of this, the inductors charge for elongated time and give more output voltage. On the other hand if the duty cycle of the pulse high, then capacitors wont be able to charge and the converter will fail. The ways of action of the converter is shown in fig4.

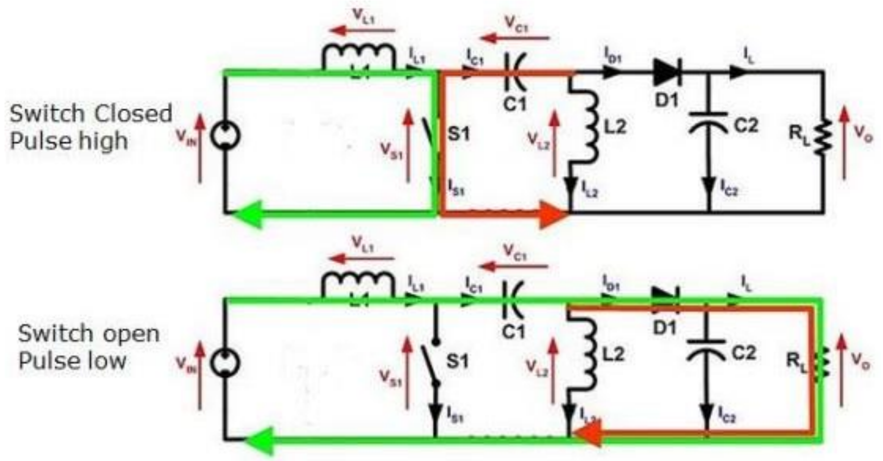

Fig4. Operation of SEPIC converter

In SEPIC converter potentiometer controlled PWM allows for control of the output during working, but it is not able to hold a constant output with a variable input. This is preferred in the SEPIC converter applications that require automation to correct an input voltage. The easiest method to uphold a persistent output is to make use of a feedback loop which will alter the output without human intervention. The feedback loop is capable to increase the duty cycle to increase the amount produced when the output is minimum and decrease it when the output is maximum.

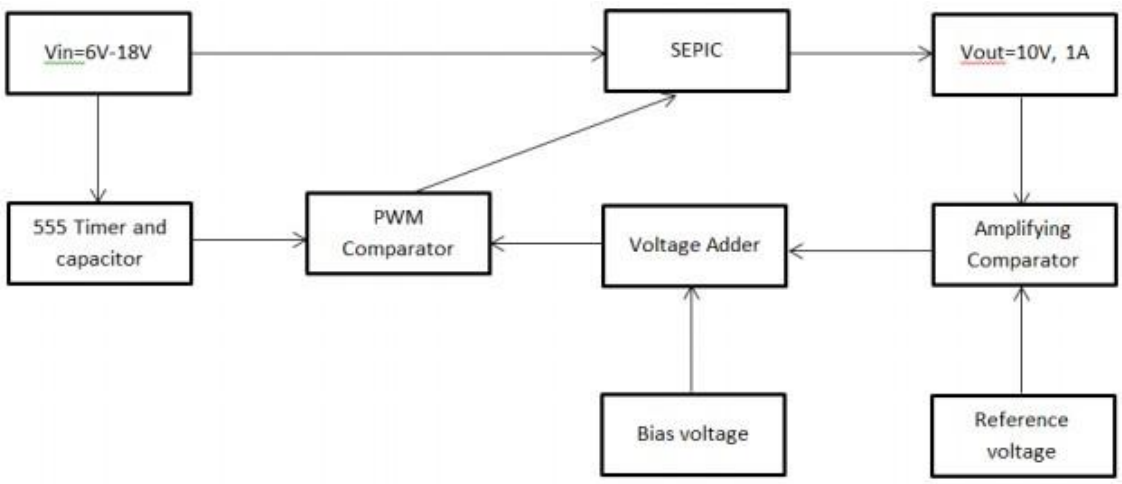

Fig5. Feedback loop controlled PWM for SEPIC converter

2.4 Implementation of control using microcontroller:

An eight bits low cost microcontroller PIC 16F874A is used for the implementation of control loop. A resistor Rs is connected in series with the LED string, is used to sense current. This sensed current of LED is a DC current which contains a less amount of second order ripple content. In order to filter out the sensed LED current low pass filter is needed. This filtered LED current is given to the microcontroller which should be compared with the required LED lamp current and expected to give the decision with escalating or declining the duty cycle until the steady state is reached.

3. Simulation And Experimetal Results

3.1 MiR-375 inhibition affects MCF-7 breast cancer cell proliferation

With the objective to analyse the achievability of the suggested driver, a design of a 60 W and 500 mA LED lamp is chosen with the specifications such as supply voltage:230 V, Supply frequency is 50 Hz, Switching Frequency is 20 kHz. The rated output voltage and current is 120V and 300mA respectively. The prototype was fabricated using the above specifications. The model was simulated using PSIM tool. A comparison has been made between the conventional and modified SEPIC.

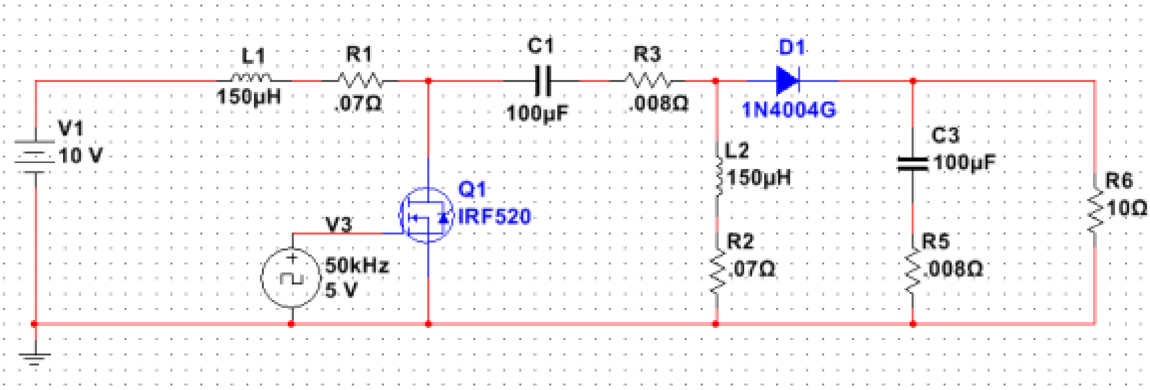

Fig 6. Simulation of SEPIC converter

Fig. 6 shows the waveform of the capacitor voltage for both the modified and conventional SEPIC converter. It is lucid that the voltage of the capacitor *C* in modified converter is a DC voltage with a small second order harmonic, but in the conventional SEPIC the voltage is the rectified supply voltage. It can be observed that the modified SEPIC converter gives the benefit of abridged voltage stresses when compared with the conventional SEPIC converter. Fig. 7 gives the voltage waveform of the capacitor C, current through it and applied PWM pulses for the specified values of input voltage and current

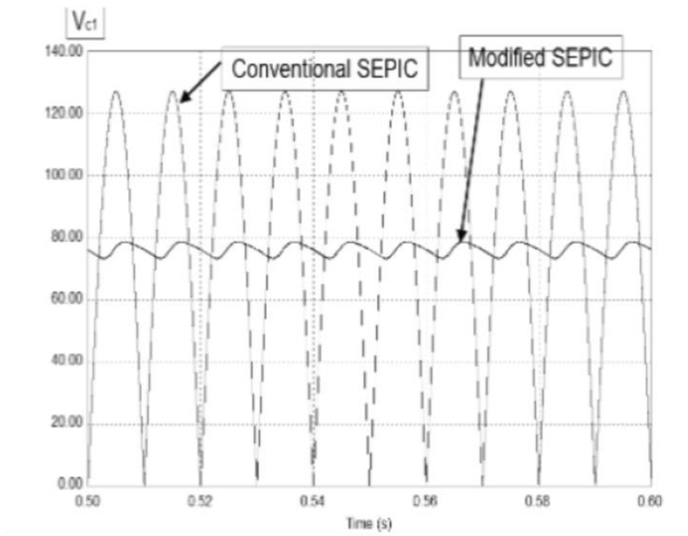

Fig. 7 Capacitor Voltage in Conservative and modified SEPIC converter with AC supply mains

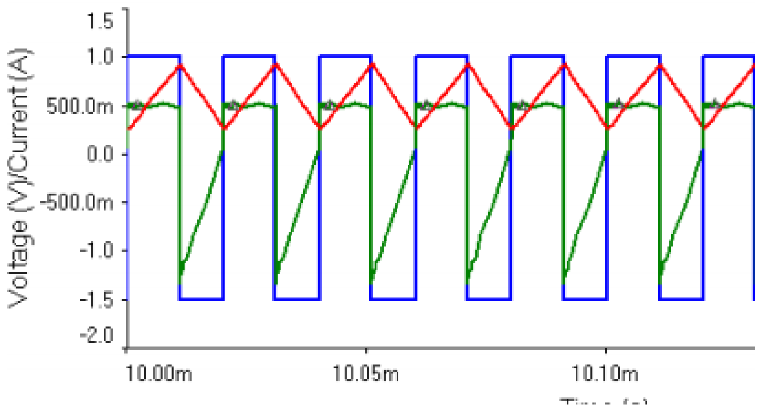

Fig 8. Voltage and current in the capacitor and PWM pulses

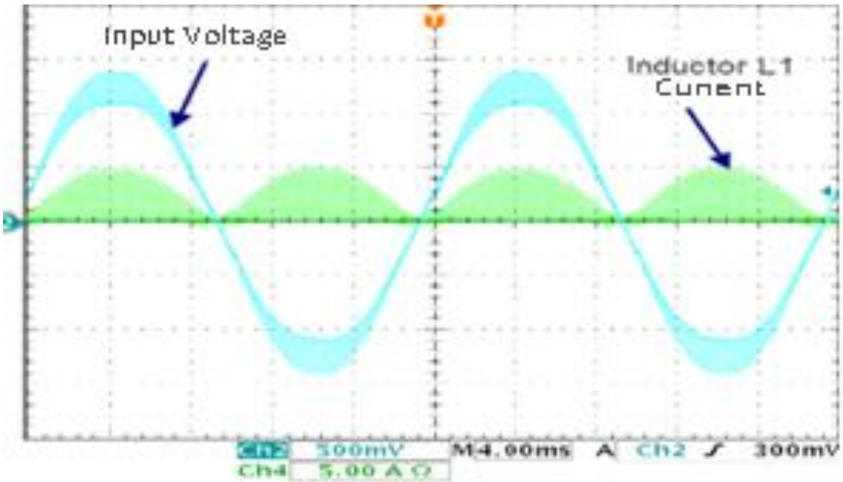

Fig.9. supply voltage and current in inductor

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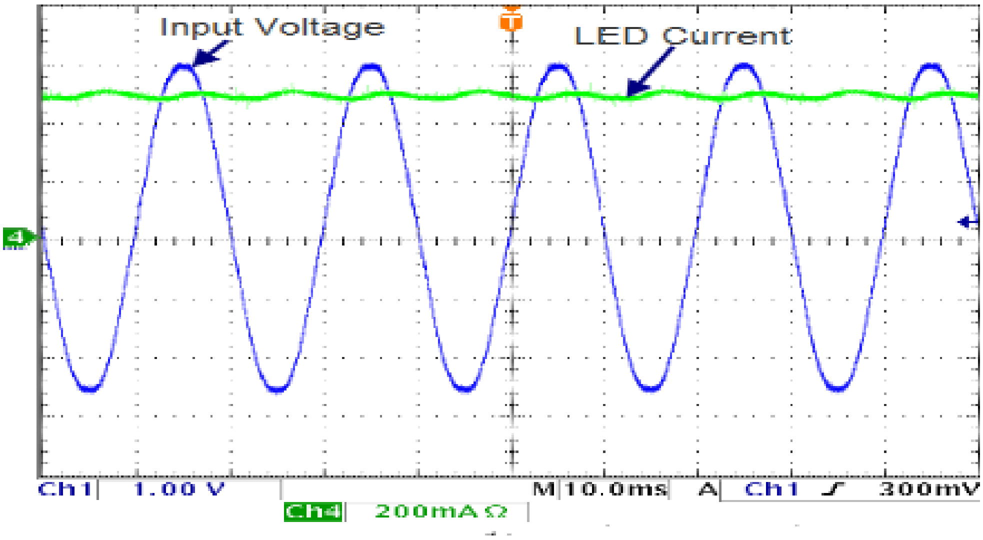

Fig.10. Supply voltage and LED current

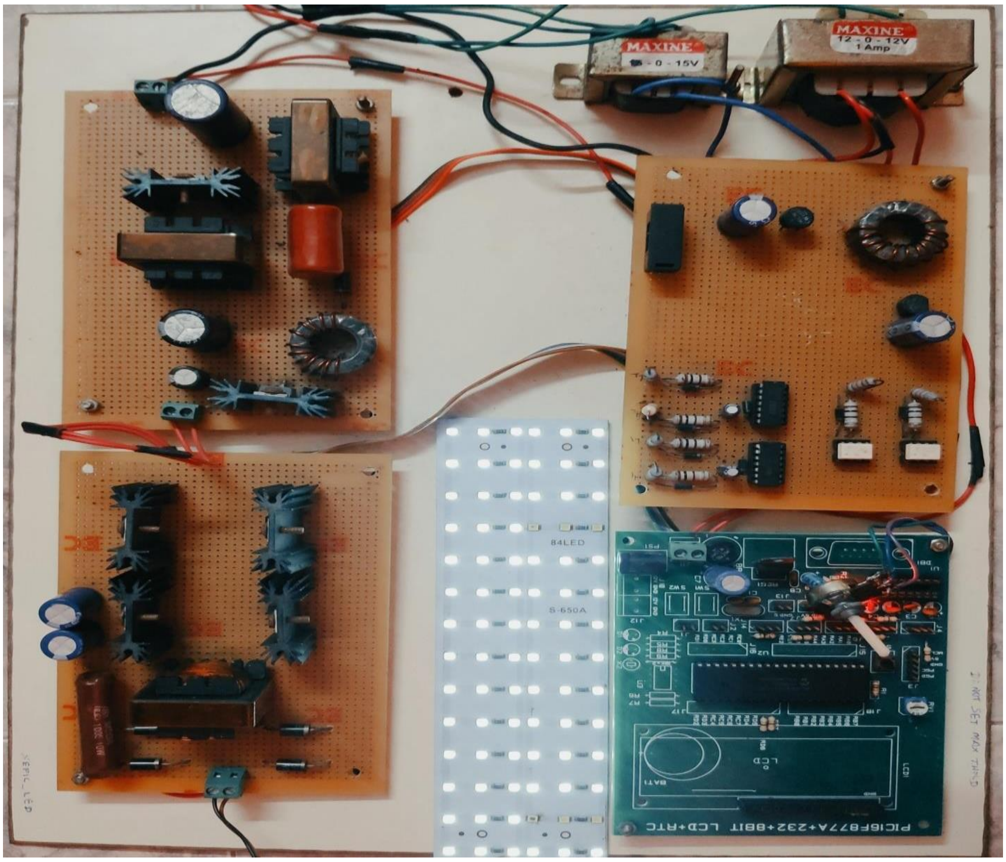

Fig 11 Laboratory prototype developed

Figure 9 and 10 gives the graph for the supply voltage and current through the inductor. Figure 11 displays the laboratory prototype that has been built and experimentally tested for verification., inductor current and LED current.

5. Conclusion

This paper proposed a capable design of a low power light emitting diode (LED) driver that offers a soft switched SEPIC converter and an equal stacked high recurrence series L-C full inverter. The introduced framework involves a rectifier fed buck derived power factor regulator (PFC) unit which lessens the harmonic distortion of the line current by further developing the sending-end power factor. The design contains a feedback loop to control the activity of the converter by changing the duty cycle. The soft switching application respects to reduced inner electromagnetic interference (EMI) commotion. It uses the minimal expense 8 bit microcontroller as a regulator. The hypothetical computations and the control calculation for the driver have been portrayed exhaustively. A research facility model has been constructed and tentatively tried for confirmation. It has been found that powerful variable and low part voltage stresses can be accomplished.

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